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Even If Approved, Globalstar's TLPS Will Underperform Free Wi-Fi On (Tens Of) Millions Of Existing Devices

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Disclosure: The author is short GSAT. The author wrote this article themselves, and it expresses their own opinions. The author is not receiving compensation for it. The author has no business relationship with any company whose stock is mentioned in this article.

Summary

- Statements by the CEO implying "every Wi-Fi device out there" only needs a software/firmware upgrade to support "carrier grade" TLPS are directly refuted by analysis of detailed manufacturer data.
- Quantitative analysis clearly shows (tens of) millions of existing devices will underperform Wi-Fi Channels 1-11 in the 2.4GHz band, both in terms of range and throughput.
- The source data comes from a manufacturer supplied "S2P file" that includes key RF filter measurements sampled in 0.5MHz steps across the entire 2.4GHz Wi-Fi band.

Disclosure: The author is short GSAT.

"In fact every Wi-Fi device out there has the ability to see the spectrum as long as it is enabled through a software or firmware push. So the whole ecosystem is there. It can take-off immediately and I think that's why people are having conversations with us."

- Jay Monroe, 2013 Q1 Earnings Call

"Every chip in every device can already see channel 14 if it's told it's allowed to."

- Jay Monroe, Bloomberg FirstWord, December 11, 2014

"Jim -- it's almost free. If you think about how a network like this gets built out, it's almost viral in nature....People buy quality...period, full stop...If you've got a product that is better than something that is off the rack, some people will pay for it."

- Jay Monroe, Mad Money, November 17, 2014

"TLPS network will be 'carrier grade' "

- Jay Monroe, Bloomberg FirstWord, December 11, 2014

Because 99% of the power in the TLPS channel exists in 17 MHz of the 22 MHz channel, the highest attenuation of these filters does not impact it.

- Twitter User attributing this quote to Globalstar's technical analysis of potential filter issues

Avago has sold more than 150M Wi-Fi filters since 2012. The highest volume part has been the ACPF-7124.

- Avago presentation, August 2014

With much written for and against Globalstar's (NYSEMKT:GSAT) TLPS proposal, I will assume readers have some level of background on the subject. Throughout the article, links to further reading are included.

Key Takeaway: RF filters render TLPS worse than free Wi-Fi - far from "carrier grade"

TLPS Operation for any device with RF Filter analyzed will:

- **Likely experience range reduction of at least 30%.**
- **Almost certainly not operate at signal levels where free Wi-Fi achieves 6.5Mbps and 13Mbps data rates.**
- **Most likely not operate at signal levels where free Wi-Fi achieves 19.5Mbps data rate.**
- **Underperform at any signal level where free Wi-Fi achieves 26Mbps to 58.6Mbps data rates.**
- **Fail to achieve 65Mbps operation even at signal levels 3dB above the threshold necessary to do so.**
- **Completely lose 6% of the "subcarriers" at 17dB above the level necessary for 65Mbps operation, with a total 15% falling below the 65Mbps threshold level. ("17db above" ~= "50 times the power of")**

Basis of Analysis:

- **Analysis performed using detailed design data provided by the RF filter manufacturer. Data easily obtained directly from the companythrough the company's customer support website.**
- **Wi-Fi Filter analyzed is the highest volume part in a family of products that has sold more than 150M units since 2012. The same filter likely found in smartphones such as the iPhone, Samsung Galaxy, and possibly iPad versions supporting both Wi-Fi and LTE.**
- **This type of analog RF Filter is not programmable "*through a software or firmware push".* Ever.**

What is Globalstar's TLPS Proposal?

Simply put, TLPS would be a license to use Wi-Fi's Channel 14 in the 2.4GHz frequency band. The latest and highest-performing version of Wi-Fi at 2.4GHz is 802.11n. Channel 14's use of 802.11n is currently prohibited around the world.

2.4 GHz					
Channel Number	Center Frequency	North America (FCC)	Europe (ETSI)	Japan	ROW
1	2412	Yes	Yes	Yes	Yes
2	2417	Yes	Yes	Yes	Yes
3	2422	Yes	Yes	Yes	Yes
4	2427	Yes	Yes	Yes	Yes
5	2432	Yes	Yes	Yes	Yes
6	2437	Yes	Yes	Yes	Yes
7	2442	Yes	Yes	Yes	Yes
8	2447	Yes	Yes	Yes	Yes
9	2452	Yes	Yes	Yes	Yes
10	2457	Yes	Yes	Yes	Yes
11	2462	Yes	Yes	Yes	Yes
12	2467	No	Yes	Yes	Yes
13	2472	No	Yes	Yes	Yes
14	2484	No	No	802.11b only	No

Figure 1: 2.4GHz Wi-Fi Channels Around the World

As publicly envisioned, TLPS will use current Wi-Fi standards as the basis for their system. **Globalstar's claim that TLPS will be "Carrier Grade" implies it will perform better than freely available Wi-Fi Channels 1-13 (1-11 in North America).** The following analysis assumes TLPS will be based on the 802.11n Wi-Fi standard. Given current worldwide restrictions**, it is unlikely ANY 802.11n-based devices have undergone even the most basic performance characterization while operating on Channel 14**.

To my knowledge, this is the first publicly-disclosed quantitative analysis of TLPS's "Wi-Fi Filter Issue". Investors, prospective partners, and the FCC should expect AT LEAST this level of analysis from Globalstar before making any major investment or regulatory decision.

NOTE: Globalstar currently operates a mobile satellite service in competition with companies like Iridium. According to their latest 10K, the FCC authorized Globalstar to use 1610-1618.725MHz (8.725MHz uplink bandwidth) for phone-to-satellite communications, and 2483.5-2500MHz (16.5 MHz downlink bandwidth) for satellite-to-phone communication. On November 13, 2012, Globalstar petitioned the FCC to allow them to combine the lower 11.5MHz of their satellite downlink channel with the unlicensed frequency range 2473MHz-2483.5MHz and operate a service on Wi-Fi Channel 14 (2473-2495MHz). While debating their TLPS proposal, it is important to remember Globalstar's license only covers the upper ~52% of Wi-Fi Channel 14.

Does "every Wi-Fi device out there" really have "the ability to see the spectrum as long as it is enabled through a software or firmware push"?

Since no device on the planet is allowed to use 802.11n on Channel 14, this is an interesting claim. The technical translation of having "the ability to the see the spectrum" means analog RF circuitry must not materially impair an 802.11n signal being transmitted on Channel 14. There is a single RF component that will determine whether this claim is true: The bandpass RF filter sitting between the device's antenna and digital signal processing chain (many refer to this as the "ISM-Band Filter").

The first point to note about any commercial RF filter for consumer applications like Wi-Fi is that they cannot be programmed "through a software or firmware push". While these components will exhibit temperature-related changes during normal operation, they are not programmable. Period. Full Stop.

This class of device encompasses (at least) higher-end smartphones such as the Apple iPhone and Samsung Galaxy. Versions of the iPad and Kindle may also contain such a filter if they support both Wi-Fi and LTE.

Avago Technologies is one of the top suppliers for this type of Wi-Fi RF Filter,selling more than 150 million since 2012. This analysis is limited to their highest volume part, the ACPF-7124.

The data comes in the form of "S Parameter" (or "S2P") files. Most analog component manufacturers will provide these files upon request. I simply made a request through Avago's customer support site.

All S2P files contain detailed RF data taken at frequencies across the filter's designed operating range. For instance, the 7124 S2P file contains data from 100MHz to 8.5GHz. The measurements from the 2.2GHz to 2.8GHz are taken in 0.5MHz steps, while measurements outside this range are taken every 5MHz. Included in these measurements is the detailed attenuation data at each frequency point.

Side Note: I also obtained the S2P file for Avago's Access Point variant of this filter, the ACFF-1024. The 1024 and 7124 have identical insertion loss profiles. Globalstar says they'll have custom AP's built for TLPS. Whether they realize it or not, this is absolutely necessary from a hardware perspective. Any system with an ACFF-1024 in the Access Point and a ACPF-7124 in the client device would suffer 2X the effects detailed below. For their upcoming trial, someone should ask what kind of filter Ruckus uses in their Access Point, and whether this filter (or whatever Wi-Fi filter is used) was removed for the trial. If so, does that create an FCC emissions issue, and why has that not been disclosed?

Assuming "carrier grade" means TLPS/Channel 14 will operate just as well as free Wi-Fi Channels in the 2.4GHz band, TLPS performance must be measured relative to these.

(click to enlarge)

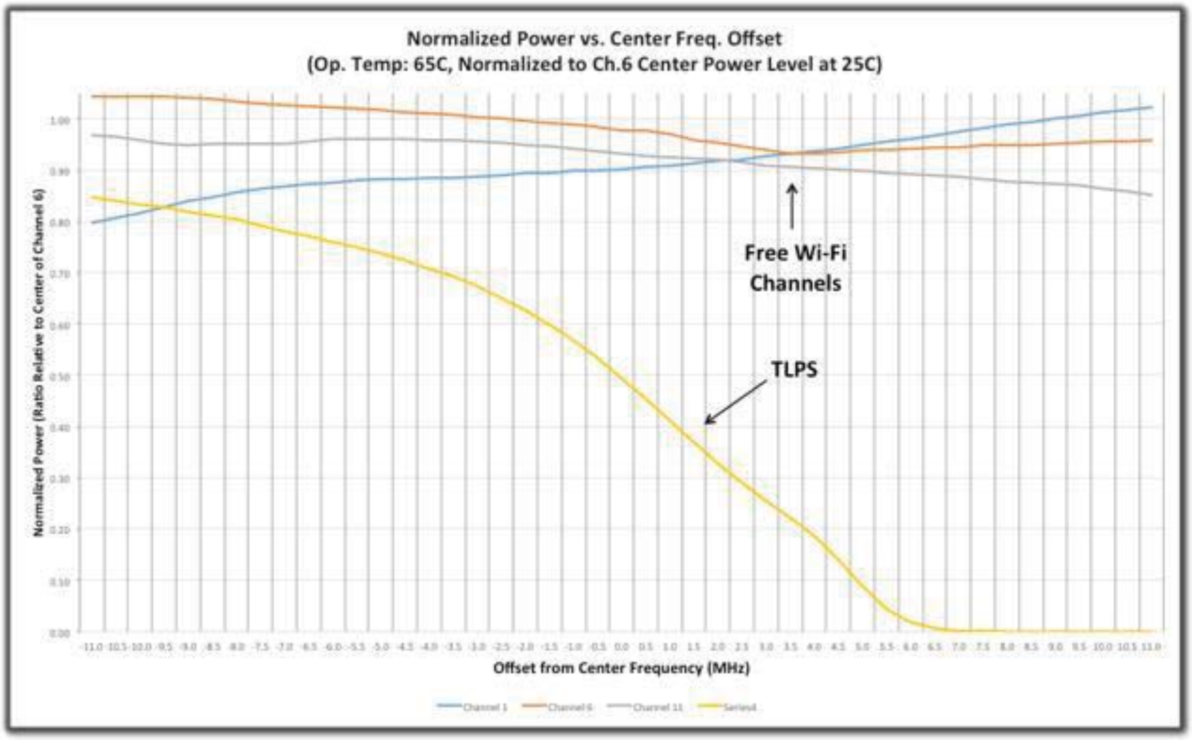
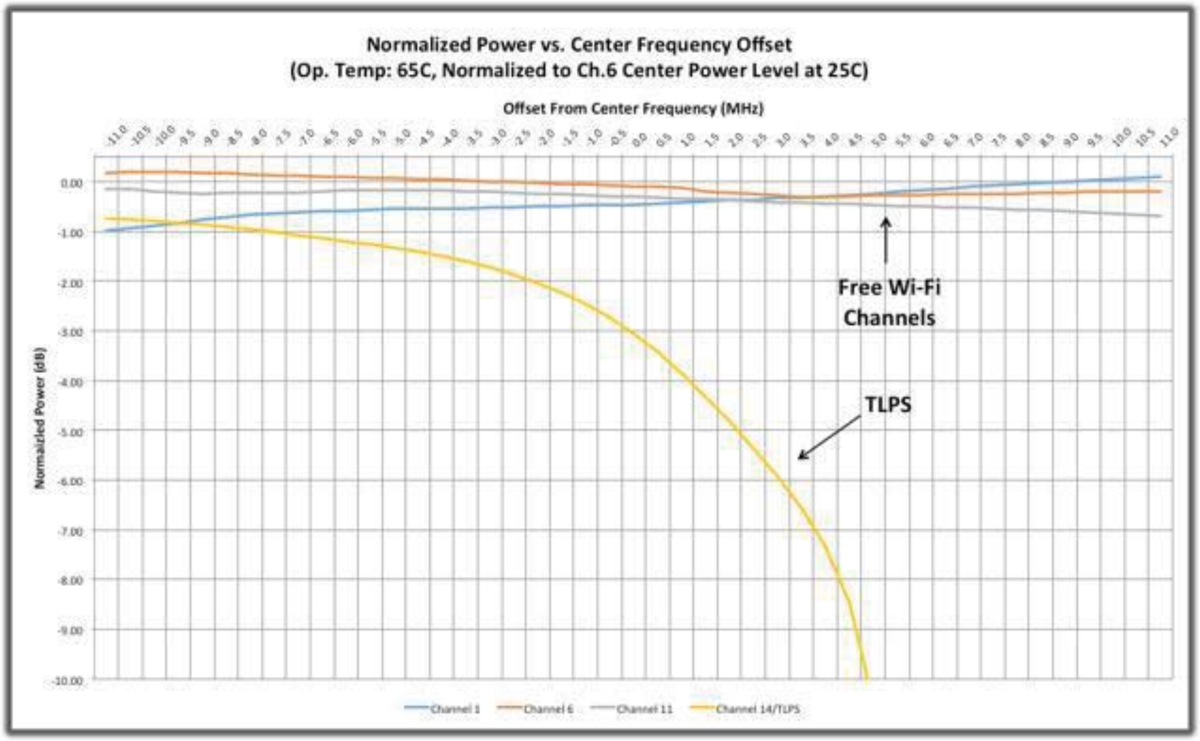


Figure 2: Relative Attenuation Effects of ACPF-7124 on Channels 1, 6, 11, and 14/TLPS (Linear Power Scale, Assumes Filter Power RatioOutput Power at 2437MHz is 1.00mW at a 25C Operating Temperature)

(click to enlarge)



(click to enlarge)

Figure 3: Relative Attenuation Effects of ACPF-7124 on Channels 1, 6, 11, and 14/TLPS (Log Power Scale, Assumes Filter Output Power at 2437MHz is 0dBm at 25C Operating Temperature)

Some important notes regarding the plots above:

- All power levels are normalized as follows: The ACPF-7124's S2P file lists insertion loss levels in dB. At 2437MHz (Channel 6 center frequency), the insertion loss is -1.0779dB. Subtracting this value from all S2P insertion loss values normalizes everything relative to the filter's insertion loss at the center of Channel 6, measured at 25^{o}C (Table 1 indicates why temperature reference is important).

- The horizontal scale shows relative offset (in MHz) from the channel's center frequency. In order to translate to an absolute frequency value, simply take the offset value and add the relevant channel's center frequency. For example, the absolute frequency for Channel 1 at the -11MHz offset is 2401MHz (2412MHz center minus 11MHz).

- Figure 2's vertical scale is a linear measure of the "Power Ratio". To generate the linear scale, I simply convert the normalized dB level to a power ratio (with Channel 6's center frequency, at 25^{o}C, being the 1.00 power level). If we assume the power measured at the center of Channel 6 (at 25^{o}C) is 1mW, then a power ratio of 0.50 equates to 0.5mW. Figure 3's vertical scale is in dB, the most common unit of measure for things like insertion loss. The linear plot is provided to give non-engineers an idea of how log-scale dB plots translate to RF power levels. For example, a -3dB level translates to a power decrease of ~50% vs. the reference level. Assuming no obstructions, a 3dB decrease in signal power results in a~30% decrease in range .

NOTE: If you follow the link to Pasternack s FSPL calculator, do two computations:

1. Distance=**1km**, Freq=2.475GHz(TLPS center), Tx Gain=0db, Rx Gain=**0dB**
2. Distance=**0.7km**, Freq=2.475GHz,Tx Gain=0dB, Rx Gain= -**3dB**

Step 1 FSPL=100.3dB ~= Step 2 FSPL=100.2dB (i.e.: ~Equal FSPL for 30% reduction in range)

- According to Avago, normal component operating temperatures will range from 65°C to 85°C. Components inside a phone/ computer/etc. operate at temperatures much higher than that felt by the user. Due to "Temperature Motion", the filter's passband will "shift left" as the temperature rises. The following table details the effect assuming TLPS channel transmission.

ACPF-7124 Temperature Motion	
TLPS/Channel 14 Center Freq.:	2484 MHz
ACPF-7124 Temco Figure:	-30 ppm/C
Temperature of S2P File Data:	25 C
Op. Temp. (degr C)	**Shift vs. 25C (MHz)**
35	-0.7
45	-1.5
55	-2.2
65	-3.0
75	-3.7
85	-4.5

Table 1: ACPF Temperature Motion

It is important to highlight Figures 2 and 3 represent the filter's relative performance at the LOW end of normal operating temperature. As later tables will show, temperature motion has a minimal impact on Channels 1 through 11 since they're already well within this filter's designed passband**. Since Channel 14 overlaps the filter's upper "transition band", temperature motion has a material effect on TLPS**. Assigning the reference power level at 25°C (temperature at which the S2P data is taken) allows us to measure the relative effect of temperature motion on all Wi-Fi channels under analysis.

While Figures 2 and 3 show the difference in the attenuation profile for TLPS vs. three free Wi-Fi channels, it is important to quantify the cumulative effect. The following tables compute "Integrated Total Power" as follows:

- At the output of the 7124, assume the power level (at 25°C!) measured in every 0.5MHz "frequency bin" across Channel 6 is 1mW/45 (there are 45 0.5MHz-step measurements in the S2P file for each 22MHz Wi-Fi channel). Integrating across the channel gives a 1mW power level. Real-world levels are much lower, but ranging from -30dBm down to minimally functional levels less than -80dBm. However, assuming they're within the filter's operating range, the absolute reference level does not affect the analysis.

NOTE: When we analyze the +/- 9MHz information-carrying portion of the channel, the number of 0.5MHz frequency bins drops from 45 to 37, and computations are adjusted accordingly.)

- With the above assumption, individual insertion level dB values (from the S2P file) can be converted to mW values, and we can perform the same total power calculation (divide each mW value by 45 and sum across the band). With the reference power level and temperature being fixed, we can quantitatively compare aggregate power levels across channels at a fixed temperature, as well as assess affects for a single channel across different operating temperature levels.

(click to enlarge)

Relative Power Across Entire Channel (+/- 11MHz from Center)

All Power Levels Normalized to (Relative to) the Center of Channel 6 (2437MHz)

Channel ->	1	6	11	14/TLPS		1	6	11	14/TLPS
Integrated Total Power	Linear Scale (1mW Ref Level)					Log Scale (in dBm)			
At 25C	0.88	0.99	0.93	0.55		-0.53	-0.03	-0.29	-2.61
At 65C (Low Op Temp)	0.91	0.98	0.92	0.45		-0.40	-0.07	-0.34	-3.45
At 85C (High Op Temp)	0.93	0.98	0.92	0.40		-0.32	-0.10	-0.38	-4.02
Channel 14/TLPS vs.	1	6	11			1	6	11	
	(% Power vs. Specified Channel)					(in dB,Relative to Specified Channel)			
At 25C	62%	55%	59%			-2.08	-2.58	-2.32	
At 65C (Low Op Temp)	49%	46%	49%			-3.06	-3.38	-3.11	
At 85C (High Op Temp)	43%	40%	43%			-3.71	-3.94	-3.65	

Table 2: Integrated Total Power of Channels 1, 6, 11, and TLPS/14 & Relative Power of TLPS/14 to Channels 1, 6, and 11 (Full 22MHz Channel Bandwidth)

At the lower end of the 7124's normal operating temperature, Channel 14 will lose > 50% of its power relative to Channel 1, 6, and 11. With 3.38dB lower power at 2484MHz (Ch14 center), we should expect TLPS's range will be about 1/3 less than Channel 6 at 65^{o}C.

It is important to note the information-carrying portion of the channel does not span the entire +/- 11MHz of a Wi-Fi channel. A common configuration of the 802.11n PHY layer contains 56 sub-carriers, spaced apart by 0.3125MHz. Some simple math shows the "information bandwidth" of a signal spans +/- 8.75MHz around the channel's center frequency. The following table narrows computations to +/- 9MHz around the center frequency.

(click to enlarge)

Relative Power Across Information Carrying Portion of Signal (~+/- 9MHz from Center)

All Power Levels Normalized to (Relative to) the Center of Channel 6 (2437MHz)

Channel ->	1	6	11	14/TLPS	1	6	11	14/TLPS
Integrated Total Power	Linear Scale (1mW Ref Level)				Log Scale (in dBm)			
At 25C	0.89	0.99	0.94	0.57	-0.51	-0.03	-0.28	-2.43
At 65C (Low Op Temp)	0.91	0.98	0.93	0.46	-0.40	-0.09	-0.33	-3.39
At 85C (High Op Temp)	0.93	0.97	0.92	0.39	-0.33	-0.12	-0.36	-4.07
At 85C with +1.5MHz MV*	0.94	0.97	0.91	0.33	-0.27	-0.14	-0.41	-4.85
Channel 14/TLPS vs.	1	6	11		1	6	11	
	(% Power vs. Specified Channel)				(in dB, Relative to Specified Channel)			
At 25C	64%	58%	61%		-1.91	-2.40	-2.15	
At 65C (Low Op Temp)	50%	47%	49%		-3.00	-3.31	-3.06	
At 85C (High Op Temp)	42%	40%	43%		-3.74	-3.96	-3.71	
At 85C with +1.5MHz MV*	35%	34%	36%		-4.58	-4.71	-4.45	

*MV: Center Frequency Manufacturing Variance from Device to Device is ~+/- 1.5MHz

Table 3: Integrated Total Power of Channels 1, 6, 11, and TLPS/14 & Relative Power of TLPS/14 to Channels 1, 6, and 11 (Limited to 18MHz of Information Carrying Bandwidth)

The change from +/- 11MHz to +/- 9MHz makes little difference in the "Integrated Total Power" of Channel 14 (0.46mW for 18MHz vs. 0.45mW for 22MHz), and the relative power levels remain virtually unchanged. ***Narrowing our analysis to the 18MHz "information bandwidth", Channel 14 still has less than 50% of the power of free Wi-Fi channels, implying a decrease in range of at least 30%.***

Table 3 includes an additional line item showing the "worst-worst case" scenario. In addition to "Temperature Motion", there will be inherent device-to-device manufacturing variances in the center frequency of the filter. This variance will likely be about +/- 1.5MHz around the designed center frequency. Devices exhibiting a negative variance will present additional attenuation to the TLPS signal. The "worst-worst case" scenario will be a device with a center frequency 1.5MHz below design, operating at the high end of the operating temperature. In this case, the TLPS signal will have 34-36% the power of free Wi-Fi channels, implying a > 40% decrease in range.

A Twitter user (@stockdoc3) posted a series of tweets that, I'm guessing, were regurgitated from Globalstar's technical expert. One such gem was "Because 99% of the power in the TLPS channel exists in 17 MHz of the 22 MHz channel, the highest attenuation of these filters does not impact it." Table 3 refutes this statement. Period. Full stop.

Will TLPS be "Carrier Grade" at even the shortest distances, and/or most benign signal conditions?

As mentioned earlier, 802.11n effectively divides each Wi-Fi channel into 56 sub-carriers.

(click to enlarge)

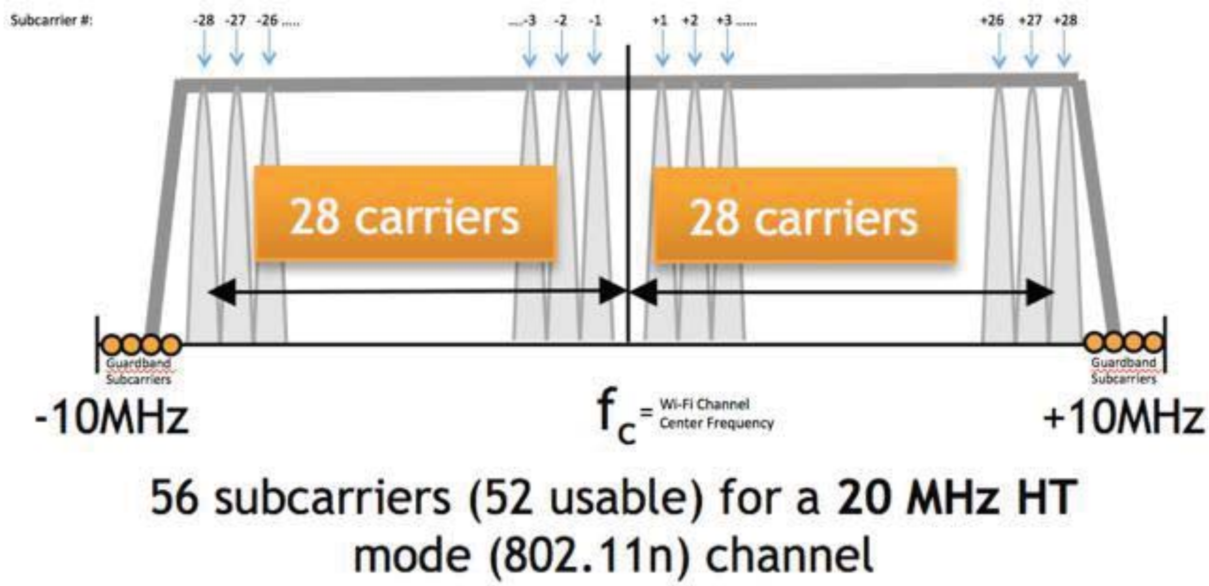


Figure 4: Wi-Fi Channel Subcarrier Map (Annotated Version from anAruba Presentation)

Of the 56 subcarriers, 52 transmit data while 4 are "Pilot" carriers (-21, -7, +7, +21) used for synchronization purposes.

The 802.11n standard allows for a wide variety of operating modes denoted by a Modulation and Coding Scheme (MCS) index value. A partial snapshot of this table is shown below.

MCS index	Spatial streams	Modulation type	Coding rate	Data rate (Mbit/s)			
				20 MHz channel		40 MHz channel	
				800 ns GI	400 ns GI	800 ns GI	400 ns GI
0	1	BPSK	1/2	6.5	7.2	13.5	15
1	1	QPSK	1/2	13	14.4	27	30
2	1	QPSK	3/4	19.5	21.7	40.5	45
3	1	16-QAM	1/2	26	28.9	54	60
4	1	16-QAM	3/4	39	43.3	81	90
5	1	64-QAM	2/3	52	57.8	108	120
6	1	64-QAM	3/4	58.5	65	121.5	135
7	1	64-QAM	5/6	65	72.2	135	150

Table 4: MCS Index Table

Though 802.11n supports multiples of the data rates shown above, this "limited by the minimum number of antennas in use on both sides of the link" (per Wikipedia page). We will assume a single spatial stream throughout the following, though the comparative results would hold for higher numbers.

In normal operation, the "MCS rate" (referred to as MCS0, MCS1, etc.) is automatically set during operation with the primary determining factor being received signal power. Table 5 specifies the discrete signal levels necessary to achieve the different MCS rates (See Table 20-22 of the 802.11n-2009 specification).

(click to enlarge)

MCS Index	Data Rate (Mbps)	Min. Req'd Power (dBm)	Upper Bound (dBm)	Middle of MCS Range (dBm)
0	6.5	-82	-79	-80.5
1	13.0	-79	-77	-78.0
2	19.5	-77	-74	-75.5
3	26.0	-74	-70	-72.0
4	39.0	-70	-66	-68.0
5	52.0	-66	-65	-65.5
6	58.5	-65	-64	-64.5
7	65.0	-64	-30	-47.0

Table 5: Received Signal Power Necessary for the Different MCS Rates

The following tables compare individual sub-carrier power levels for Wi-Fi Channel 6 and TLPS. The side-by-side comparisons assume identical receive signal levels at the input to the Wi-Fi filter. The numbers also assume the lower end (65ºC) of the normal component operating temperature range. Comparative results deteriorate even further for TLPS as temperature increases.

NOTE: Notice the "subcarrier tables" display frequency steps aligned with their specified spacing of 0.3125MHz. The S2P files have a frequency spacing of 0.5MHz from 2200-2800MHz. Before generating the following tables, I imported the S2P data into Matlab, and resampled from 0.5MHz to 0.3125MHz using Matlab's "interp1" function. This allows for a precise alignment of ACPF-7124 insertion loss measurements with the Channel 14/TLPS subcarriers.

Mid-Point of MCS7		
Channel	**6**	**TLPS**
Rx Level (dBm)	-47.0	-47.0
Sub-Carrier (SC)	**Pwr(dBm)**	**Pwr (dBm)**
-28	-46.8	-47.9
-27	-46.9	-47.9
-26	-46.9	-47.9
-25	-46.9	-47.9
-24	-46.9	-48.0
-23	-46.9	-48.0
-22	-46.9	-48.1
Pilot		
-20	-46.9	-48.1
-19	-46.9	-48.2
-18	-46.9	-48.2
-17	-46.9	-48.2
-16	-46.9	-48.3
-15	-46.9	-48.3
-14	-47.0	-48.4
-13	-47.0	-48.4
-12	-47.0	-48.5
-11	-47.0	-48.6
-10	-47.0	-48.6
-9	-47.0	-48.7
-8	-47.0	-48.8
Pilot		
-6	-47.0	-49.0
-5	-47.0	-49.1
-4	-47.1	-49.3
-3	-47.1	-49.4
-2	-47.1	-49.5
-1	-47.1	-49.7
Carrier		
1	-47.1	-50.1
2	-47.1	-50.4
3	-47.2	-50.6
4	-47.2	-50.9
5	-47.2	-51.2
6	-47.2	-51.5
Pilot		
8	-47.3	-52.2
9	-47.3	-52.5
10	-47.3	-52.9
11	-47.3	-53.2
12	-47.3	-53.6
13	-47.3	-54.1
14	-47.3	-54.7
15	-47.3	-55.5
16	-47.3	-56.6
17	-47.3	-58.1
18	-47.3	-60.1
19	-47.3	-62.4
20	-47.2	-65.1
Pilot		
22	-47.2	-70.7
23	-47.2	-73.7
24	-47.2	-76.7
25	-47.2	-79.7
26	-47.2	-82.8
27	-47.2	-86.0
28	-47.2	-89.3
MCS Index	**Ch.6**	**TLPS**
7	100%	85%
6	0%	0%
5	0%	2%
3&4	0%	4%
2	0%	2%
1&0	**0%**	**2%**
No Signal	**0%**	**6%**
% SCs at Lower MCS (vs. Rx)	0%	15%

MCS7 Min Level+0.5dBm		
Channel	**6**	**TLPS**
Rx Level (dBm)	-63.5	-63.5
Sub-Carrier (SC)	**Pwr (dBm)**	**Pwr (dBm)**
-28	-63.3	-64.4
-27	-63.4	-64.4
-26	-63.4	-64.4
-25	-63.4	-64.4
-24	-63.4	-64.5
-23	-63.4	-64.5
-22	-63.4	-64.6
Pilot		
-20	-63.4	-64.6
-19	-63.4	-64.7
-18	-63.4	-64.7
-17	-63.4	-64.7
-16	-63.4	-64.8
-15	-63.4	-64.8
-14	-63.5	-64.9
-13	-63.5	-64.9
-12	-63.5	-65.0
-11	-63.5	-65.1
-10	-63.5	-65.1
-9	-63.5	-65.2
-8	-63.5	-65.3
Pilot		
-6	-63.5	-65.5
-5	-63.5	-65.6
-4	-63.6	-65.8
-3	-63.6	-65.9
-2	-63.6	-66.0
-1	-63.6	-66.2
Carrier		
1	-63.6	-66.6
2	-63.6	-66.9
3	-63.7	-67.1
4	-63.7	-67.4
5	-63.7	-67.7
6	-63.7	-68.0
Pilot		
8	-63.8	-68.7
9	-63.8	-69.0
10	-63.8	-69.4
11	-63.8	-69.7
12	-63.8	-70.1
13	-63.8	-70.6
14	-63.8	-71.2
15	-63.8	-72.0
16	-63.8	-73.1
17	-63.8	-74.6
18	-63.8	-76.6
19	-63.8	-78.9
20	-63.7	-81.6
Pilot		
22	-63.7	-87.2
23	-63.7	-90.2
24	-63.7	-93.2
25	-63.7	-96.2
26	-63.7	-99.3
27	-63.7	-102.5
28	-63.7	-105.8
MCS Index	**Ch.6**	**TLPS**
7	100%	0%
6	0%	29%
5	0%	17%
3&4	0%	33%
2	0%	4%
1&0	**0%**	**4%**
No Signal	**0%**	**13%**
% SCs at Lower MCS (vs. Rx)	0%	100%

Table 6: Channel 6 vs. TLPS for Signal Level Required to Achieve 65Mbps Throughput *(TLPS Likely to Underperform even at 17dB above minimum signal level required to achieve 65Mbps. Right-hand table shows TLPS will definitely underperform when the receive signal level is near the 65Mbps threshold level.)*

Mid-Point of MCS6		
Channel	6	TLPS
Rx Level (dBm)	-64.5	-64.5
Sub-Carrier (SC)	Pwr (dBm)	Pwr (dBm)
-28	-64.3	-65.4
-27	-64.4	-65.4
-26	-64.4	-65.4
-25	-64.4	-65.4
-24	-64.4	-65.5
-23	-64.4	-65.5
-22	-64.4	-65.6
Pilot		
-20	-64.4	-65.6
-19	-64.4	-65.7
-18	-64.4	-65.7
-17	-64.4	-65.7
-16	-64.4	-65.8
-15	-64.4	-65.8
-14	-64.5	-65.9
-13	-64.5	-65.9
-12	-64.5	-66.0
-11	-64.5	-66.1
-10	-64.5	-66.1
-9	-64.5	-66.2
-8	-64.5	-66.3
Pilot		
-6	-64.5	-66.5
-5	-64.5	-66.6
-4	-64.6	-66.8
-3	-64.6	-66.9
-2	-64.6	-67.0
-1	-64.6	-67.2
Carrier		
1	-64.6	-67.6
2	-64.6	-67.9
3	-64.7	-68.1
4	-64.7	-68.4
5	-64.7	-68.7
6	-64.7	-69.0
Pilot		
8	-64.8	-69.7
9	-64.8	-70.0
10	-64.8	-70.4
11	-64.8	-70.7
12	-64.8	-71.1
13	-64.8	-71.6
14	-64.8	-72.2
15	-64.8	-73.0
16	-64.8	-74.1
17	-64.8	-75.6
18	-64.8	-77.6
19	-64.8	-79.9
20	-64.7	-82.6
Pilot		
22	-64.7	-88.2
23	-64.7	-91.2
24	-64.7	-94.2
25	-64.7	-97.2
26	-64.7	-100.3
27	-64.7	-103.5
28	-64.7	-106.8
MCS Index	**Ch.6**	**TLPS**
7	0%	0%
6	100%	0%
5	0%	29%
3&4	0%	48%
2	0%	4%
1&0	0%	4%
No Signal	0%	15%
% SCs at Lower MCS (vs. Rx)	0%	100%

Mid-Point of MCS5		
Channel	6	TLPS
Rx Level (dBm)	-65.5	-65.5
Sub-Carrier (SC)	Pwr (dBm)	Pwr (dBm)
-28	-65.3	-66.4
-27	-65.4	-66.4
-26	-65.4	-66.4
-25	-65.4	-66.4
-24	-65.4	-66.5
-23	-65.4	-66.5
-22	-65.4	-66.6
Pilot		
-20	-65.4	-66.6
-19	-65.4	-66.7
-18	-65.4	-66.7
-17	-65.4	-66.7
-16	-65.4	-66.8
-15	-65.4	-66.8
-14	-65.5	-66.9
-13	-65.5	-66.9
-12	-65.5	-67.0
-11	-65.5	-67.1
-10	-65.5	-67.1
-9	-65.5	-67.2
-8	-65.5	-67.3
Pilot		
-6	-65.5	-67.5
-5	-65.5	-67.6
-4	-65.6	-67.8
-3	-65.6	-67.9
-2	-65.6	-68.0
-1	-65.6	-68.2
Carrier		
1	-65.6	-68.6
2	-65.6	-68.9
3	-65.7	-69.1
4	-65.7	-69.4
5	-65.7	-69.7
6	-65.7	-70.0
Pilot		
8	-65.8	-70.7
9	-65.8	-71.0
10	-65.8	-71.4
11	-65.8	-71.7
12	-65.8	-72.1
13	-65.8	-72.6
14	-65.8	-73.2
15	-65.8	-74.0
16	-65.8	-75.1
17	-65.8	-76.6
18	-65.8	-78.6
19	-65.8	-80.9
20	-65.7	-83.6
Pilot		
22	-65.7	-89.2
23	-65.7	-92.2
24	-65.7	-95.2
25	-65.7	-98.2
26	-65.7	-101.3
27	-65.7	-104.5
28	-65.7	-107.8
MCS Index	**Ch.6**	**TLPS**
7	0%	0%
6	0%	0%
5	100%	0%
3&4	0%	77%
2	0%	4%
1&0	0%	4%
No Signal	0%	15%
% SCs at Lower MCS (vs. Rx)	0%	100%

Table 7: Channel 6 vs. TLPS for Signal Level Required to Achieve 52.0 & 58.5 Mbps Throughput *(TLPS underperforms Free Wi-Fi in each case)*

Mid-Point of MCS2		
Channel	6	TLPS
Rx Level (dBm)	-75.5	-75.5
Sub-Carrier (SC)	Pwr (dBm)	Pwr (dBm)
-28	-75.3	-76.4
-27	-75.4	-76.4
-26	-75.4	-76.4
-25	-75.4	-76.4
-24	-75.4	-76.5
-23	-75.4	-76.5
-22	-75.4	-76.6
Pilot		
-20	-75.4	-76.6
-19	-75.4	-76.7
-18	-75.4	-76.7
-17	-75.4	-76.7
-16	-75.4	-76.8
-15	-75.4	-76.8
-14	-75.5	-76.9
-13	-75.5	-76.9
-12	-75.5	-77.0
-11	-75.5	-77.1
-10	-75.5	-77.1
-9	-75.5	-77.2
-8	-75.5	-77.3
Pilot		
-6	-75.5	-77.5
-5	-75.5	-77.6
-4	-75.6	-77.8
-3	-75.6	-77.9
-2	-75.6	-78.0
-1	-75.6	-78.2
Carrier		
1	-75.6	-78.6
2	-75.6	-78.9
3	-75.7	-79.1
4	-75.7	-79.4
5	-75.7	-79.7
6	-75.7	-80.0
Pilot		
8	-75.8	-80.7
9	-75.8	-81.0
10	-75.8	-81.4
11	-75.8	-81.7
12	-75.8	-82.1
13	-75.8	-82.6
14	-75.8	-83.2
15	-75.8	-84.0
16	-75.8	-85.1
17	-75.8	-86.6
18	-75.8	-88.6
19	-75.8	-90.9
20	-75.7	-93.6
Pilot		
22	-75.7	-99.2
23	-75.7	-102.2
24	-75.7	-105.2
25	-75.7	-108.2
26	-75.7	-111.3
27	-75.7	-114.5
28	-75.7	-117.8
MCS Index	**Ch.6**	**TLPS**
7	0%	0%
6	0%	0%
5	0%	0%
3&4	0%	0%
2	100%	29%
1&0	0%	40%
No Signal	0%	31%
% SCs at Lower MCS (vs. Rx)	100%	71%

Mid-Point of MCS1		
Channel	6	TLPS
Rx Level (dBm)	-78.0	-78.0
Sub-Carrier (SC)	Pwr (dBm)	Pwr (dBm)
-28	-77.8	-78.9
-27	-77.9	-78.9
-26	-77.9	-78.9
-25	-77.9	-78.9
-24	-77.9	-79.0
-23	-77.9	-79.0
-22	-77.9	-79.1
Pilot		
-20	-77.9	-79.1
-19	-77.9	-79.2
-18	-77.9	-79.2
-17	-77.9	-79.2
-16	-77.9	-79.3
-15	-77.9	-79.3
-14	-78.0	-79.4
-13	-78.0	-79.4
-12	-78.0	-79.5
-11	-78.0	-79.6
-10	-78.0	-79.6
-9	-78.0	-79.7
-8	-78.0	-79.8
Pilot		
-6	-78.0	-80.0
-5	-78.0	-80.1
-4	-78.1	-80.3
-3	-78.1	-80.4
-2	-78.1	-80.5
-1	-78.1	-80.7
Carrier		
1	-78.1	-81.1
2	-78.1	-81.4
3	-78.2	-81.6
4	-78.2	-81.9
5	-78.2	-82.2
6	-78.2	-82.5
Pilot		
8	-78.3	-83.2
9	-78.3	-83.5
10	-78.3	-83.9
11	-78.3	-84.2
12	-78.3	-84.6
13	-78.3	-85.1
14	-78.3	-85.7
15	-78.3	-86.5
16	-78.3	-87.6
17	-78.3	-89.1
18	-78.3	-91.1
19	-78.3	-93.4
20	-78.2	-96.1
Pilot		
22	-78.2	-101.7
23	-78.2	-104.7
24	-78.2	-107.7
25	-78.2	-110.7
26	-78.2	-113.8
27	-78.2	-117.0
28	-78.2	-120.3
MCS Index	**Ch.6**	**TLPS**
7	0%	0%
6	0%	0%
5	0%	0%
3&4	0%	0%
2	0%	0%
1&0	100%	58%
No Signal	0%	42%
% SCs at Lower MCS (vs. Rx)	100%	42%

Table 8: Channel 6 vs. TLPS for Signal Level Required to Achieve 19.5 & 13 Mbps Throughput *(At this signal level, Free Wi-Fi achieves expected throughput. At MCS2, TLPS loses 31% of the sub-carriers, and another 40% sit a lower MCS* levels. TLPS unlikely to work at all at these signal levels.*)*

This sub-carrier level analysis provides a stark view of how the ACPF-7124 will affect the throughput of TLPS vs. a free Wi-Fi channel under identical received signal levels. Note the following:

1. **Even at signal levels *17dB above*** levels where free Wi-Fi channels easily achieve the highest possible data rates, **15% of TLPS sub-carriers suffer degradation**. It is possible TLPS could not achieve 65Mbps in this situation. In fact, even at the maximum input level of -30dBm, one of the TLPS sub-carriers falls below the MCS7 threshold.
2. While free Wi-Fi achieves the highest data rate at 0.5dB above the MCS7 threshold level (as expected), 100% of TLPS sub-carriers are below this threshold. Even more shocking, 13% of the sub-carriers fall to "No Signal" levels. In this situation, with free Wi-Fi operating at 65Mbps, TLPS is guaranteed to be slower (quite possibly multiple "MCS steps" slower).
3. While free Wi-Fi achieves 19.5Mbps (MCS2), TLPS is likely to stop working. At this signal level, 31% of TLPS sub-carriers drop below the "No Signal" level, while another 40% are at MCS0/MCS1 rates.
4. TLPS will undoubtedly stop working at receive signal levels where free Wi-Fi can still achieve 6.5Mbps and 13Mbps.

Conclusions

With direct information from just one filter manufacturer, and some fairly straightforward computations, the data shows severe performance limitations of TLPS relative to free Wi-Fi channels.

Given Globalstar's prior statements, I am left with the following questions:

- Did Globalstar or their technical representatives bother to obtain S2P files from ANY Wi-Fi filter manufacturers?
- If so, did the company perform an analysis at least to the level of detail done here?
- If so, how can the company justify the comments listed at the beginning of this article?

It is my understanding Globalstar has been in communication with at least one Wi-Fi filter manufacturer regarding this problem. If Globalstar understands the scope of this problem (contrary to their public statements), let's assume they are asking manufacturers to design new filters that fully encompass Channel 14. This raises the following questions:

- How long will it take for manufacturers to design such a filter? It would not be a trivial shift of the filter's passband. According to an RF filter expert, it would likely require temperature compensation ability and might take 1-2 years to design.
- AFTER the filter is designed, how long will it take to have it designed into consumer devices before being available for widespread use?
- The filter & consumer device manufacturers won't go through the cost/effort of new designs without Globalstar's TLPS meeting some minimum level of volume expectations, likely in the 10's of millions. If you were an executive at Avago or Apple, how eager would you be to pursue the TLPS "opportunity" given the high degree of risk involved?
- According to these guys and these guys and Sprint, Band 41 starts at 2496MHz. Globalstar's 10k states their downlink channel extends to 2500MHz, meaning there is a 4MHz overlap between licenses. Has Globalstar done the diligence to understand if it is even possible to design a filter

assuming there is only a 1MHz guard band between the top edge of Wi-Fi Channel 14 (at 2495MHz) and the lower edge of Sprint's Band 41? (at 2496MHz). The issue of possible adjacent channel interference between TLPS and Sprint's Band 41 service deserves further analysis.

Author's Note: Though currently a fund manager, I have a background in many technical aspects of Globalstar's TLPS proposal. After obtaining a Bachelor (BS) and Master of Engineering (M.Eng.) degree in Electrical Engineering from Cornell University, I spent the first nine years of my career working on wireless communication systems. The last was an early MIMO-OFDM system.

During the course of writing this article, data, analysis methods, and conclusions were shared with domain experts in the area of analog RF design/manufacturing and OFDM (802.11n's modulation scheme) signal processing.